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OHMSETT (Oil and Hazardous Materials Simulated Environmental Test Tank) Tests of TOCSON (Texas Oil Spill Control, Inc.) Weir Skimmer and Gravity Differential Separator

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Leonardo, NJ

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by

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Recovery efficiency and oil recovery rate were the criteria used to measure the skimmer's performance with respect to oil slick thickness, propeller speed, waves, and tow speed. Separator performance was judged by its effectiveness in separating an oil and water dispersion with respect to percent water in the oil effluent and oil concentration in the water effluent samples. The independent variables used in testing the separator were flow rate and oil concentration of the influent liquid.

Best performance of the skimmer and separator when tested as a system occurred when the skimmer propeller was run at a speed of 620 rpm in a light oil slick of 26 mm. Under these conditions, the separator yielded effluent oil with 0.2% water content and effluent water containing 192 mg of oil/liter.

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OHMSETT TESTS OF TOSCON WEIR SKIMMER AND GRAVITY DIFFERENTIAL SEPARATOR[1]

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ABSTRACT

An evaluation of the effectiveness of the Texas Oil Spill Control, Inc. (TOSCON) weir skimmer and gravity differential separator was conducted at the U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility in October 1982. The tests were sponsored by the OHMSETT Interagency Technical Committee (OITC). The TOSCON skimmer and separator are designed and manufactured by Texas Oil Spill Control, Inc., of Conroe, Texas. The skimmer was designed to operate at intake rates up to 227 cubic meters per hour (m^3/h) alone and up to 11.4 m^3/h when operated with the oil/water separator.

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The separator achieved a best performance effluent oil sample containing less than 0.02% water. Samples taken during normal operating conditions contained an average of 2.2% water. The lowest concentration of oil in an effluent water sample was 65 milligrams per liter (mg/liter); the average concentration for all samples was 506 mg/liter of oil. Overall, the separator performed best when oil concentrations in the influent were above 40%.

The skimmer was tested in oil slicks from 1 millimeter (mm) to 31 mm thick. Oil recovery rates ranged from 0.5 to 8.6 m^3/h; the average was 2.5 m^3/h. Recovery efficiency ranged from 8 to 59%.

Best performance of the skimmer and separator when tested as a system occurred when the skimmer propeller was run at a speed of 620 rpm in a light oil slick of 26 mm. Under these conditions, the separator yielded effluent oil with 0.2% water content and effluent water containing 192 mg of oil/liter.

INTRODUCTION

In most oil spill recovery operations employing skimmers, the recovered fluid is usually high in water content unless the product is concentrated into a thick slick. As a result, a very large storage capacity for the oil/water mixture is required. Therefore, it is helpful to have a method to separate the oil from the water.

A weir-type skimmer and a gravity differential separator designed and manufactured by Texas Oil Spill Control, Inc. (TOSCON) of Conroe, Texas, were tested at the U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) facility during the period 18 through 22 October 1982.

Twenty-five tests were performed using two types of oil. The oils used were Circo Medium and Circo 4X Light, both napthenic-based oils distributed by the Sun Oil

Co. The first 13 tests were performed on the separator alone, and varied the flow rates and influent oil/water concentrations.

Three tests were performed to evaluate the skimmer's effectiveness when used without the separator. Two tests in waves with a 2 mm slick thickness were run with the skimmer stationary. In the third test, the skimmer was towed in calm water through a 1-mm slick. The separator was evaluated for its effectiveness in separating the influent oil and water mixture in all tests except the towing and wave tests.

Eight tests measured the performance of the skimmer and separator as a system varying the oil slick thickness and the skimmer propeller speed. The water concentration in the effluent oil and the oil concentration in the effluent water samples were measured for each of these tests.

In the last test, a modified set of baffles and gate were used on the skimmer to illustrate their effect on recovery efficiency.

The skimmer's performance was evaluated by calculating the following values:

$$\text{Recovery Rate (RR)} = \frac{\text{Oil and Water Volume Recovered}}{\text{Recovery Time}}$$

$$\text{Oil Recovery Rate (ORR)} = \frac{\text{Oil Volume Recovered}}{\text{Recovery Time}}$$

$$\text{Recovery Efficiency (RE)} = \frac{\text{Oil Volume Recovered}}{\text{Oil and Water Volume Recovered}} \times 100\%$$

TEST APPARATUS

The TOSCON system is comprised of an oil skimmer and a separator. When operated together, the separator is the limiting element in recovering oil; its efficiency in separating the oil and water decreases as the skimmer's throughput increases.

Skimmer

The TOSCON Skimmer is 1.83 meters (6 ft) long by 1.22 meters (4 ft) wide with a height of 0.61 meters (2 ft). It weighs approximately 90.7 kilograms (200 pounds) with a draft of approximately 432 mm (17 inches). Two pontoons on the port and starboard sides of the skimmer serve as flotation. A propeller in the stern draws oil and water through a converging channel beginning at the bow of the skimmer. Two weirs, one at the bow and the other at the center, skim the oil from the water surface into the skimmer. Each is a horizontal gate attached to the skimmer at the bottom with hinges. The bow weir can be adjusted to a admit a varying depth of fluid by the addition or reduction of ballast water inside the weir.

A hydraulic pump and a transfer pump are required to operate the skimmer. The hydraulic pump supplies power to the propeller motor on the skimmer, and the transfer pump transfers the recovered oil and water from the skimmer to the separator. The standard hydraulic pump for the unit is a Hydura-standard axial-piston pump, model PVQ06. It hydraulically drives the propeller motor, a Char-Lynn "M Series" low speed, high torque hydraulic motor (displacement 12 cm^3/rev). The pump used to transfer the oil and water is a Ramoy 300 series pump, Model Helico 367, a progressive-cavity pump. The pump's motor is powered hydraulically by the same Hydura-standard axial-piston pump as the propeller motor.

Separator

The TOSCON separator measures 0.9 meter (3 ft) wide by 2.7 meters (9 ft) long by 1.7 meters (5.5 ft) high. It is transported on a four-wheel trailer measuring 2.44 meters (8 ft) wide by 6.1 meters (20 ft) long with a height of 2.13 meters (7 ft). The trailer and the empty separator together weigh 1,513 kilograms (3,335 lb). The trailer

also carries the hydraulic pump and diesel driver, plus the transfer pump with hydraulic driver.

The separator is of the gravity differential type and uses the difference in fluid densities to separate a mixture. Two fluids with substantially different densities can be separated more efficiently and quickly than materials with a smaller difference.

Oil and water recovered from the skimmer enter the progressive-cavity transfer pump through a 2 inch connection. This fluid then enters the separator through a 2 inch pipe connected to the discharge of the transfer pump. If the skimmer is collecting 100% oil, the pumping system can bypass the separator. Outlet connections for the separated oil and water are 4 inch in diameter, but can be reduced to 2 inch. Additional facilities are necessary for storing the separated oil and water until it can be removed from the spill site.

TEST PLAN & PROCEDURES

The TOSCON Oil Skimmer-Separator System was tested three different ways. Performance data was obtained first for the separator, then for the skimmer, and lastly for the separator/skimmer system. This approach was employed for ease in evaluating the system and its component parts.

Separator

Two variables were used in evaluating the TOSCON gravity separator. The amount of medium oil in the saline water flowing into the separator was varied in the range of 3 percent to 100 percent (based on laboratory analysis of samples), and the flow rate was set to 6.8, 9.1 or 11.4 m^3/h.

The physical setup consisted of the separator, three pumps, two static mixers, two flowmeters, a bimetallic thermometer, and a sample tap (Figure 1). Oil was pumped to the separator using a Viking KK-124 pump with an electric drive and flow bypass. Saline water from the main OHMSETT test tank was supplied using a Viking HL-124 pump with a diesel drive. Both the oil and water supply lines had flowmeters. Following the flowmeters, the two lines formed a tee, which entered two 2 inch diameter Komax in-line motionless mixers (Model X020-040-1-003-22) in series. Immediately after the mixers was a sample tap and then the bimetallic thermometer. The mixed fluids then entered the separator. A Barnes pump was used to assist the gravity flow of the oil out of the separator; no pump was used for the water discharge line.

Thirteen tests were performed on the TOSCON gravity separator. Tests 1 through 4 lasted 25 minutes, with influent and effluent samples taken at intervals of 12 and 24 minutes. The remaining tests lasted 40 minutes, with influent and effluent samples taken at intervals of 18 and 38 minutes. The influent oil/water dispersion samples were taken from the sample tap immediately following the two static mixers (Figure 1). The effluent oil samples were obtained by skimming oil from within the separator adjacent to the outlet ports into a beaker, and the effluent water samples were taken at the discharge of the water hose. During normal operation, the separator contains approximately 2.3 m^3 of water and 0.5 m^3 of oil.

Skimmer

Tests on the skimmer were limited by time constraints. Two tests were performed on the skimmer to evaluate its performance when encountering waves. During the two tests, the propeller speed and slick thickness were held constant, while the wave length and height were varied. Circo Medium oil was used in these tests.

The test setup consisted of the skimmer, a pump, a flexible boom, and a fire hose. The skimmer was positioned in the boom perpendicular to the direction of the incoming waves and held in position with ropes (Figure 2). Waves were not damped by the boom, since it was rigged to be open to the oncoming waves. Oil was added during the tests to maintain a constant slick thickness and a water jet from a fire hose was used to herd the oil at the mouth of the boom into a constant oil slick area. A Wilden M-15 pump was used to remove accumulated oil from the skimmer and transfer it to the auxiliary bridge tanks for measurement and sample collection. Each test lasted 10 minutes.

The oil recovery data was obtained from the auxiliary bridge recovery tanks using the following procedure. The volume of recovered fluid was determined by measuring the height of fluid in each recovery tank with a meterstick. The water was then stripped and the residual oil height measured. Oil samples were taken with a stratified sample thief. The samples were then analyzed in the laboratory using ASTM D1796-81 to determine the water content of the recovered oil for calculating recovery efficiency and oil recovery rate. Tables 1 and 2 give the properties of the test oils and OHMSETT tank water.

One test evaluated the skimmer while towed at a speed of 0.5 knot through a Circo Medium oil slick 1 mm thick. The skimmer was towed with the open end first, and the equipment setup was the same as in the wave tests excluding the boom and the fire hose (Figure 3). In addition, four oil distribution nozzles on the main bridge were used to distribute a 1 mm oil slick approximately 6.1-m (20 ft) wide in front of the skimmer. To control the width of the oil slick encountered by the skimmer, two 5/8" braided polypropylene guide ropes were attached to the skimmer's crossbeam at its throat to maintain a slick width of 0.71 m (2.3 ft). Four ropes were attached for skimmer control, two at the bow for towing and two at the stern for stability. Data and sample collection techniques were identical to the wave test procedures. The test duration was 5 minutes, 12 seconds.

Separator & Skimmer

During this phase of the testing, the system performance of the skimmer and separator operating together was evaluated. The skimmer was tested by controlling two independent variables, the slick thickness and the propeller speed. One of these was changed while all other variables were held constant, including the recovery rate of the transfer pump. As these two variables were altered, the oil-to-water ratios entering the separator changed. This allowed for collection of efficiency data on the separator. The test fluid for these tests was Circo 4X Light oil.

The physical setup consisted of the separator, skimmer, four lengths of Goodrich boom, and two pumps (Figure 4). The skimmer was centered in a circle 8.9 m in diameter formed by four lengths of Goodrich square-D booms. As oil was removed from the skimmer with the transfer pump located on the separator's trailer, an equal amount was added inside the booms from the main bridge. This was done to maintain a constant slick thickness throughout a test. The oil and water discharge from the separator had separate lines to the auxiliary bridge tanks for data and sample collection. In each line a pump was used to transfer the oil or water up to the auxiliary bridge tanks (Figure 5).

Nine different tests were run on the combined separator and skimmer as a system. Tests 19 through 28 (23 and 24 were not run) each lasted 20 minutes, with data and samples taken only during the last ten minutes. Due to the change in oil-to-water concentrations for each test, the first ten minutes were used to establish a steady state in the separator. Influent samples were taken at the beginning and end of each ten-minute test period. Effluent samples were taken in the middle of each test period. The influent samples were taken by partially opening a valve on the bypass of the transfer pump located on the separator's trailer. Effluent oil samples were taken from within the separator adjacent to the outlet port. Effluent water samples were

taken at the water discharge into the auxiliary bridge tanks. The auxiliary bridge tanks were again used for data and sample collection as in the skimmer tests. Test 29 was a special test designed to check the effectiveness of a different set of baffles and gate.

RESULTS AND DISCUSSION

Evaluation Criteria

Performance of the separator alone was evaluated by measuring the percent of oil in the influent, the percent of water in the effluent oil and the concentration of oil in the effluent water expressed in milligrams of oil per liter of water.

Performance of the skimmer tested alone and in combination with the separator was evaluated by determining Recovery Rate (RR), Oil Recovery Rate (ORR), and Recovery Efficiency (RE), using the formulas given in the Introduction. Another formula for these tests determined the time-averaged slick thickness, calculated as follows:

$$T = 40.7 \times \frac{2V + (Q_i - Q_o) \times t}{2A}$$

where:

T	=	the time-averaged slick thickness (mm)
40.7	=	conversion coefficient $\frac{ft^2 - mm}{gal}$
V	=	the initial oil volume (gal)
Q_i	=	the oil flow rate into the boom (gpm)
Q_o	=	the oil flow rate out of the boom (gpm)
t	=	the elapsed time (min)
A	=	the average cross-sectional area of the boom circle (ft^2)

Separator

Thirteen different tests were performed on the separator. One of three flow rates, (6.8, 9.1, or 11.4 m^3/h) was used while the ratio of oil to water was changed. Influent and effluent oil/water concentrations were calculated by laboratory analysis of samples. Flow meter readings were used during the test to establish approximate oil/water concentration of influent into the separator. All the lab sample data as reported were averaged from two samples, one taken in the middle and one at the end of each test.

Tests at the higher flow rates (11.4 or 10.2 m^3/h) showed the trend for percent water in effluent oil to drop as the amount of oil in the influent increased. See Table 3 for the results of Tests 1 through 4. The effluent oil samples were 1.5% to 4.0% water, and the effluent water samples had an oil concentration of 351 to 2,351 mg/liter. The influent oil concentration range for lab samples was from 6 to 66%. For these tests, the water content in the effluent oil stabilized between 3.8 and 4.0% when the influent oil concentration was below 30% (Figures 6 and 7).

Five tests were performed at a flow rate of 6.8 m^3/h of influent with a range in oil concentration from 3 to 56%. As the influent oil concentration increased, the amount of water in effluent oil dropped, ranging from 2.5% with 3% oil influent to 1.3% with 56% oil influent. See Table 3 for results of Tests 5 through 9. At influent oil concentrations of 24% or higher, the water content in the effluent oil stabilized between 1.3 and 1.4%. The concentration of oil in the water effluent exhibited no definable trend, ranging from 108 to 1003 mg of oil per liter.

Tests 10 and 11 used an influent flow rate of 9.1 m^3/h for a fluid with 12 and 43% oil, respectively. Results of these two tests supported the trend of the quality of both oil and water effluent to increase as influent oil concentration increased. As the oil concentration of influent increased by 31 percentage points, the water content of the oil effluent dropped 1.1 percentage points and the oil content of the water effluent was 989 mg/liter less.

Tests 12 and 23 had flow rates of 9.1 m^3/h and were performed to investigate the effect of unusual operating conditions on the separator. Test 12 was conducted by inclining the separator 24.2 cm lengthwise and 10.2 cm along its width. The effect on the effluent streams was slight. Adding 100% oil to the separator for ten minutes during Test 13 resulted in the separator filling with oil, since oil was pumped in faster than it could gravity drain.

Skimmer

Three tests were run on the skimmer alone, two wave tests and one tow test. In the wave tests, decreasing the wavelength from 5.9 to 2.9 meters and increasing the height of the waves from 0.18 to 0.47 meters, resulted in a decrease of 21 percentage points in recovery efficiency and a 20% decrease in oil recovery rate. When the skimmer was towed through a one millimeter oil slick, it recovered 88% of the slick encountered. The RE and ORR were 8% and 0.7 m^3/h, respectively.

Separator & Skimmer

Nine different tests were performed on the TOSCON Oil Skimmer-Separator as a system. The first four tests evaluated the performance of the skimmer by changing the slick thickness and the remaining tests checked its performance by varying the skimmer's propeller speed (Figure 5). The efficiency of the separator was also obtained by sampling the influent as provided by the skimmer and comparing these samples with effluent samples (Table 5).

Tests 19 through 29 were performed at a skimmer propeller speed of 620 rpm and oil slick thickness ranging from 7 to 26 mm. These tests showed an increase in skimmer RR as the slick thickness increased with a corresponding increase in oil

concentration of influent into the separator. The percentage of water in the oil effluent increased as the slick thickness increased. The effluent oil ranged from less than 0.02% to 20% water, and the effluent water contained from 99 to 294 mg of oil per liter.

Tests 26 through 28 were performed with an average slick thickness of 28 mm and an average propeller speed of 490 rpm. Under these conditions, the skimmer's ORR ranged from 1.3 to 2.5 m^3/h and the RE ranged from 22 to 41%. The separator influent as proved by the skimmer had an oil percentage of from 22 to 48%. The effluent oil contained water content in the effluent oil ranged from 9 to 20% and the quality of the effluent water ranged from 65 to 153 mg of oil per liter (Figures 8, 9, and 10). Test 29 used a different baffle and gate, resulting in a 7% lower RE than Test 25 which was an equivalent test with a standard gate.

CONCLUSIONS & RECOMMENDATIONS

Separator

The following conclusions for the separator are based on the laboratory analysis of influent oil samples. The influent lab sample data were accurate due to the use of two static mixers in series followed immediately by a sample tap.

The amount of water in the effluent oil varied only 0.4% with a flow rate ranging from 9.1 to 11.4 m^3/h (40 to 50.2 gpm) when the oil concentration in the influent was less than 50%. When the influent oil concentration dropped to less than 35% and the separator was operated at a flow rate of 6.8 m^3/h (29.9 gpm) instead of 11.4 m^3/h (50.2 gpm), the water content in the effluent oil dropped 54%. When the influent oil concentration was 50% or more, the effect on water content was negligible.

Oil concentration in the effluent water averaged 307 mg/liter with a flow rate between 6.8 m^3/h (29.9 gpm) and 11.4 m^3/h (50.2 gpm) when the oil concentration of

the influent was above 50%. The concentration of oil in the effluent water rapidly increased as the oil concentration in the influent dropped below 35% when tested at flow rates between 6.8 and 11.4 m^3/h. When running medium oil through the separator with an oil concentration of 50% or greater, the separator design flow rate of 11.4 m^3/h should be used since lower flow rates increase performance relatively little (Figures 6 and 7). At oil concentrations of less than 44%, reducing the flow rate through the separator improves the efficiency appreciably.

Skimmer

During the two wave tests, the skimmer's RE increased by 21 percentage points when the wave height was reduced and the wave period lengthened, in contrast to a drop in ORR of 0.5 m^3/h during these tests. See Table 4 for results of Tests 14 and 15. The skimmer recovered 88% of the 1 mm slick it encountered with an RE of 8% and an ORR of 0.7 m^3/h (3.1 gpm) when towed at 0.5 kt in calm water for the single towing test performed. Shakedown runs showed the skimmers' tendency to nose down into the water at tow speeds greater than 2.0 kt.

Separator & Skimmer

Recovery efficiency data collected by taking samples from the transfer pump bypass valve on the separator compared quite closely with the auxiliary bridge sample results; average sample data agreed within one percentage point of each other for Tests 19 through 28. (Recovery efficiencies from the auxiliary bridge tanks may not reflect the skimmer's performance accurately for a specific test, but give an average performance of a number of tests.) The percent oil in the influent bypass valve samples gives an accurate description of the skimmer's performance during a test, but

only for a portion of the test. This difficulty is inherent when operating the two systems together, but also gives the best analysis of the equipment working together.

Best performance of the combined system was achieved at a propeller speed of 620 rpm in a light oil slick of 26 mm. The skimmer, with an RE of 53% and an ORR of 4.1 m^3/h provided an influent to the separator of 58% oil. Under these conditions, the separator yielded effluent oil with 0.2% water content and effluent water containing 192 mg of oil/liter. The tests on the skimmer and separator as a system were stationary tests. The propeller speed is a key performance variable since an excessive speed will push oil out of the skimmer before the transfer pump can remove it, and a slow rate may not pull enough oil into the skimmer to keep up with the transfer pump recovery rate thus lowering recovery efficiency.

The separator should be operated with a minimum discharge line size of 3 in.; it comes with a 4 in. diameter outlet. Otherwise, the separator cannot gravity drain at rates fast enough to match the inflow. This overload or back-up condition occurs in the separator when operating near its maximum design capacity or at high recovery efficiencies. This was found while testing the separator and skimmer together with influent flow rates greater than 6.0 m^3/h and oil concentrations above 50% using 2 in. diameter discharge lines. When a back-up did happen, as in Tests 21 and 26, oil had to be flushed out of the separator by running water throught it. These tests have a high percentage of water in the effluent oil because of overload conditions in the separator during the test or previous test.

Additional tests should be conducted to evaluate the effect of varying the flow rate of the skimmer's transfer pump.

TABLE 1. TEST OIL PROPERTIES

Oil Type	Specific gravity	Viscosity cSt*	Viscosity cSt*	SFT† dynes/cm	IFT† dynes/cm	% water & sediment
Circo 4X light	0.892	12.6 @ 22°C	9.0 @ 29°C	32	12.1	0.1
Circo medium	0.925	529.7 @ 12°C	99.5 @ 35°C	33.6	11.5	0.2%

†SFT = Surface facial tension, IFT = Interfacial tension

*cSt = centistokes

TABLE 2. PHYSICAL PROPERTIES OF TANK WATER

pH	7.1
Specific gravity	1.013
Temperature (°C)	23.7
Salinity (ppt)	17.5
Conductivity (umhos)	25,600
Suspended solids (mg/l)	7.3

TABLE 3. TEST RESULTS FOR SEPARATOR[1]

Test No.	Influent[2] % H_2O	Influent[2] % Oil	Flow Rate (m^3/h)	Effluent[2] %H_2O in Oil	Effluent[2] mg. of oil liter H_2O
1	94	6	11.4	3.8	2,351
2	71	29	11.4	4.0	1,152
3	48	52	11.4	1.9	560
4	34	66	10.2	1.5	351
5	97	3	6.8	2.5	301
6	88	12	6.8	1.9	1,003
7	76	24	6.8	1.4	487
8	44	56	6.8	1.3	210
9	47	53	6.8	1.4	108
10	88	12	9.1	4.5	1,433
11	57	43	9.1	3.4	444
12*	61	39	9.1	2.8	398
13	0	100	9.1	N/A	N/A

1. Circo Medium oil was used in these tests.

2. Values listed are an average of two samples, one taken in the middle and one at the end of each test.

* Trailer with separator inclined 24.2 cm lengthwise and 10.2 cm along its width.

TABLE 4. TEST RESULTS FOR SKIMMER[1]

Test No.	Propeller Speed (rpm)	Slick Thickness (mm)	Tow Speed (kt)	Waves Length (m)	Waves Height[2] (m)	PR (m^3/h)	ORR (m^3/h)	RE (%)
14	370	2	0.0	5.48	0.18	5.5	2.0	59
15	340	2	0.0	2.9	0.47	6.0	1.6	38
16	280	1	0.5	calm water		5.0	0.7	8

1. Circo Medium oil was used in these tests.

2. Average height of the highest 10% of the waves.

TABLE 5. TEST RESULTS FOR SEPARATOR AND SKIMMER[1]

Test No.	Propeller speed (rpm)	Slick Thickness (mm)	Influent* Lab Samples %H_2O	Influent* Lab Samples % Oil	RR (m^3/h)	ORR (m^3/h)	RE (%)	Effluent % H_2O in Oil	Effluent mg of oil liter H_2O
19	620	7	85	15	7.1	0.5	7	< 0.02	294
20	620	10	79	21	7.5	1.8	24	2.0	227
21	620	23	35	65	10.9	8.6	79	20.0	172
22	620	21	67	33	6.8	2.9	42	7.4	99
25	620	26	42	58	7.7	4.1	53	0.2	192
26	410	25	78	22	6.1	1.3	21	20.0	65
27	250	28	75	25	6.9	1.8	26	9.0	153
28	810	31	52	48	6.0	2.5	42	14.0	122
29**	620	32	49	51	N/A	N/A	N/A	N/A	N/A

* Values listed are an average measurement from two samples, one taken at the beginning and one at the end of each test.

** Special test with different baffles and gate, requested by manufacturer. The separator was in an overload condition during this test. The slick thickness was estimated.

1. Circo 4X Light oil was used in these tests.

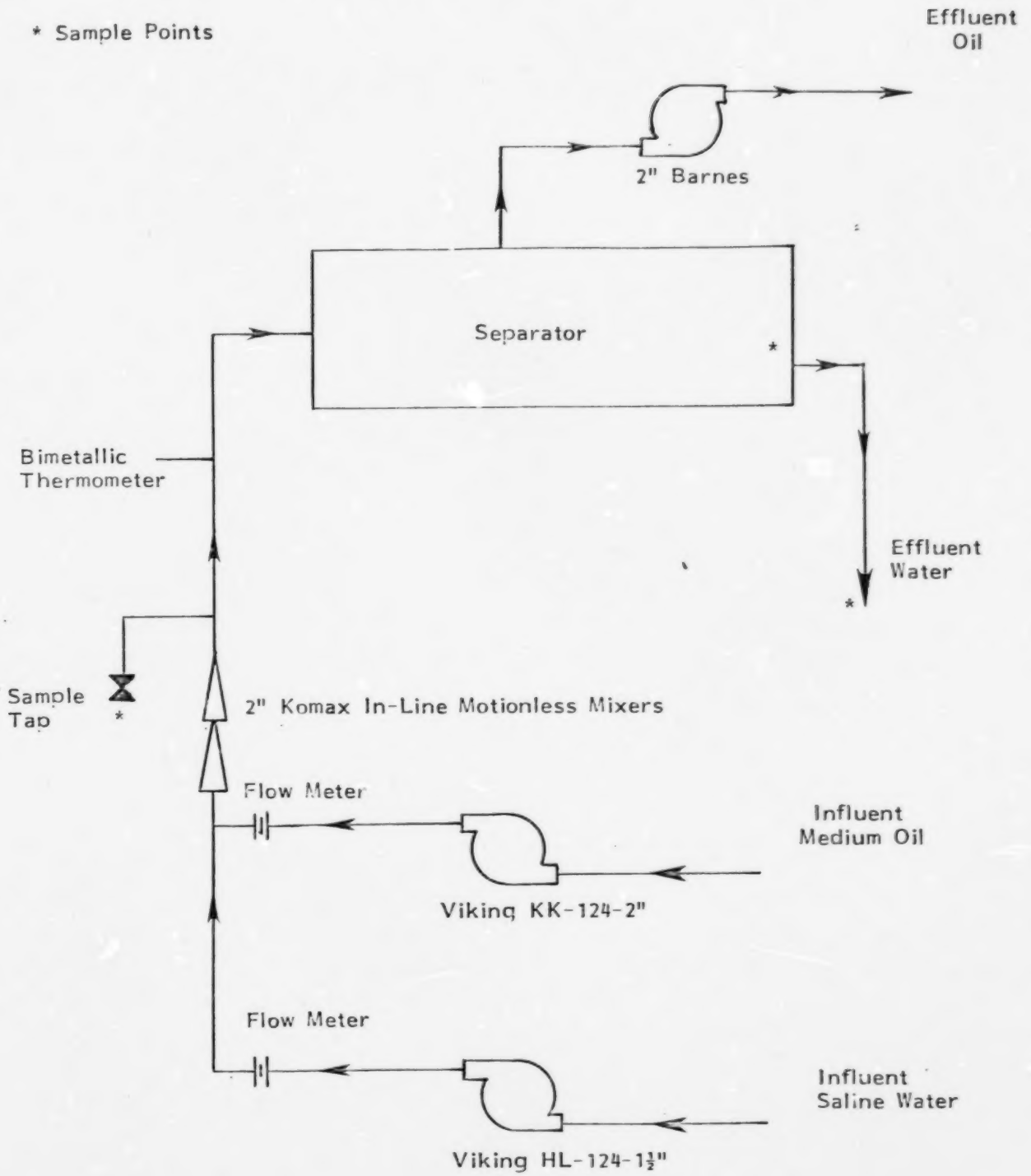

Figure 1. Schematic drawing of testing setup for the tests of the separator alone, showing location of pumps, mixers, flowmeters, thermometer, sample tap and direction of flow through the components.

Figure 2. Photograph of the skimmer showing details of the rigging for stationary wave tests. The waves are proceeding in an approximately oblique straight line, from the bottom of the photograph to the top. Note the V-shape configuration of the boom with the open end towards the incoming waves.

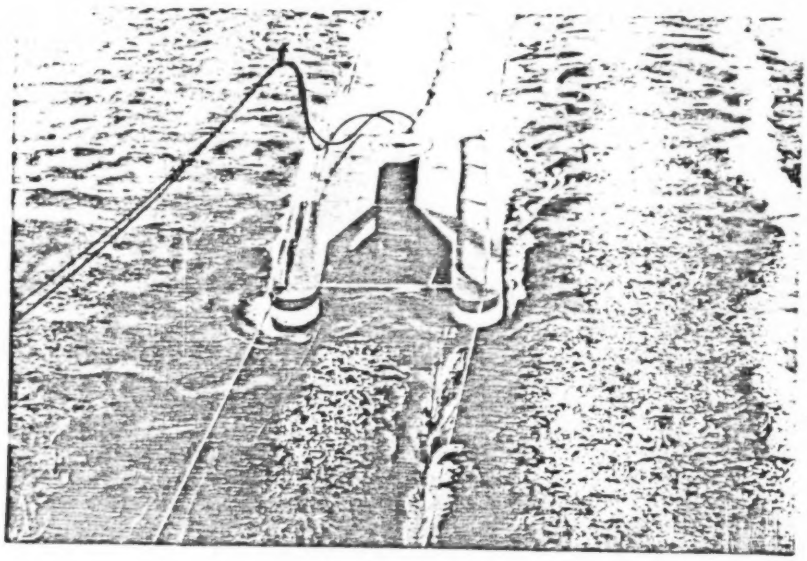

Figure 3. Photograph of the skimmer during the tow test. Note the slick guided by ropes and the suspended hydraulic lines.

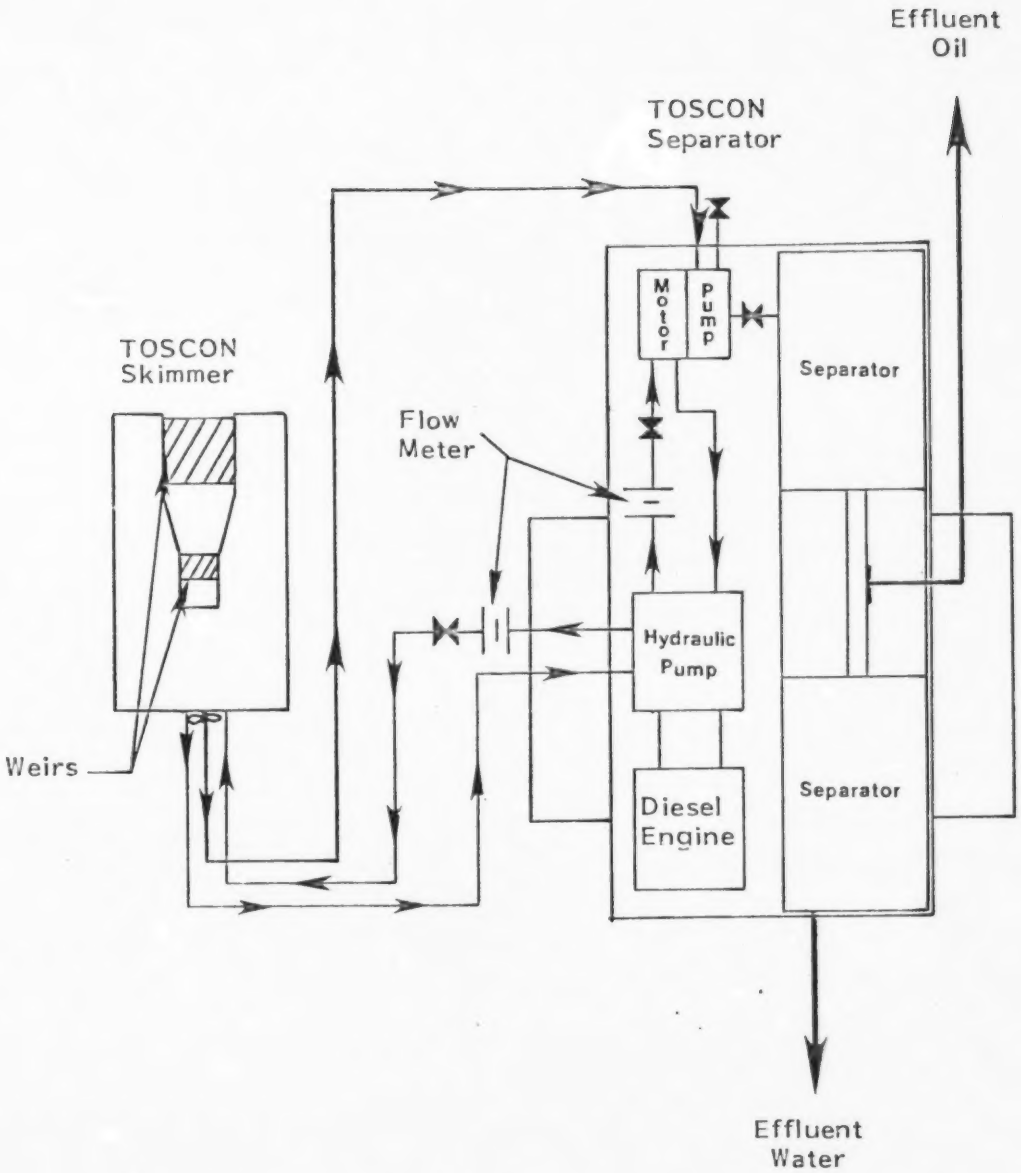

Figure 4. Schematic of setup for tests of the combined skimmer and separator as a system, showing location of pumps, motors, flowmeters and direction of fluid flow through the system.

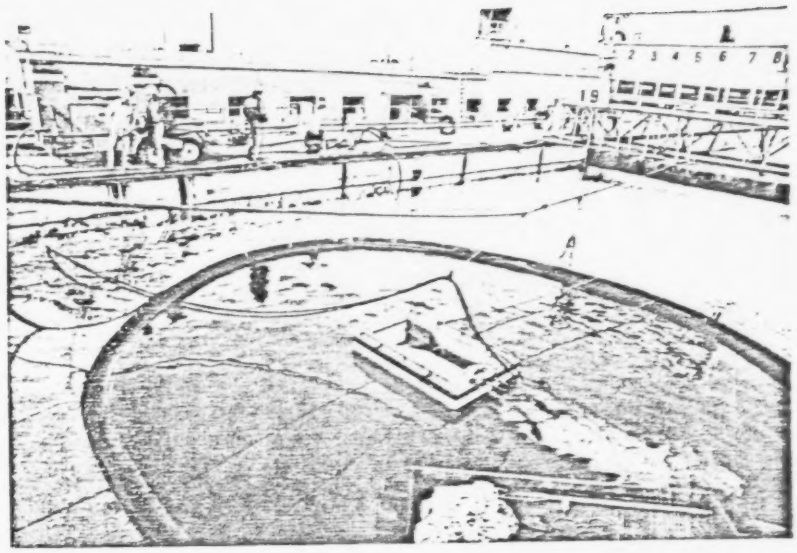

Figure 5. Photograph of the setup for the tests on the complete TOSCON skimmer/separator system showing the boom circle enclosing the oil, and the hoses and lines between the skimmer, the separator and the recovery tanks.

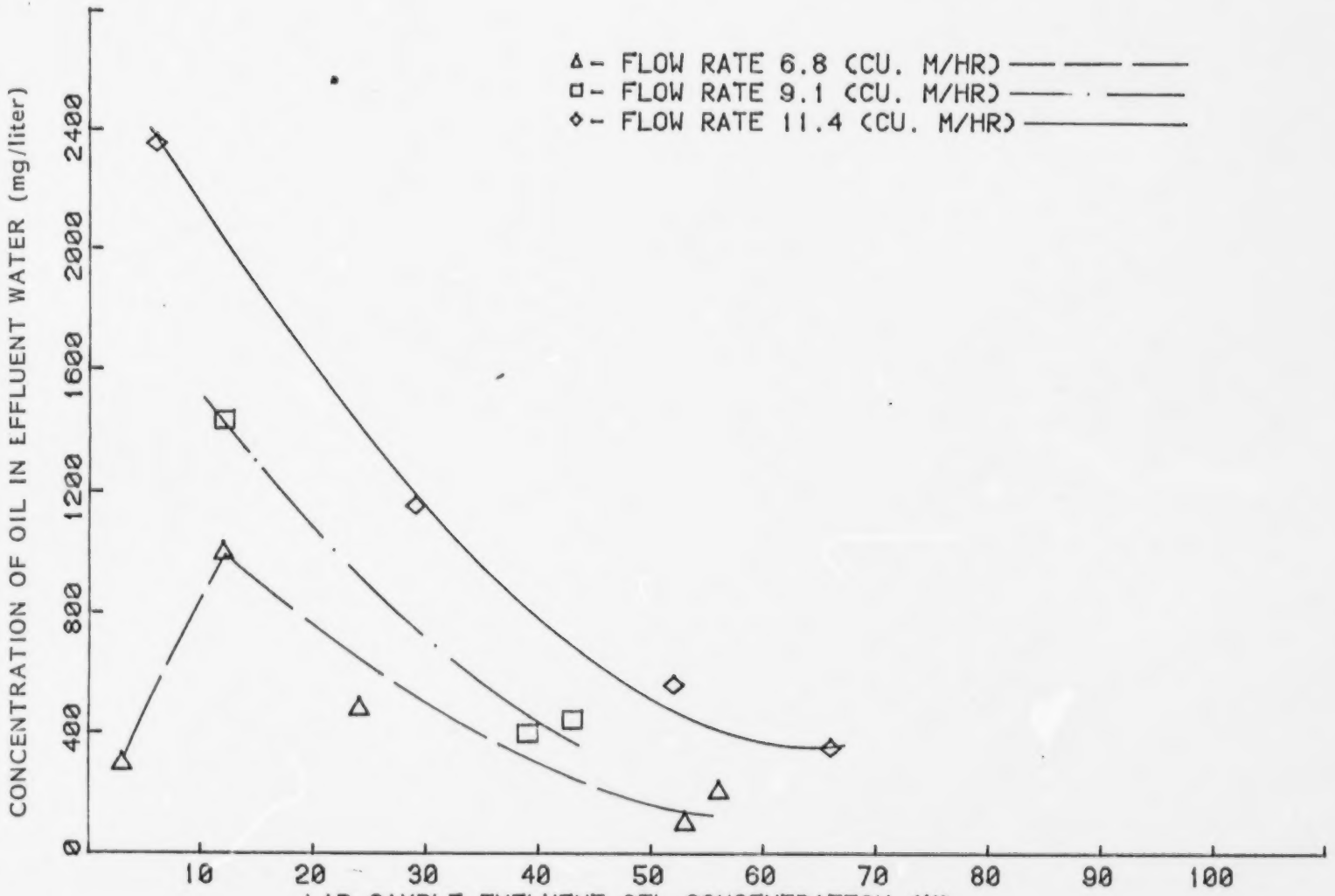

Figure 6 : SEPARATOR PERFORMANCE, MEDIUM OIL

This graph shows the effect on the water effluent of varying the medium oil concentration of the influent introduced into the separator at three different flow rates. The effluent water quality is expressed by the amount of oil in a liter of effluent water measured in milligrams.

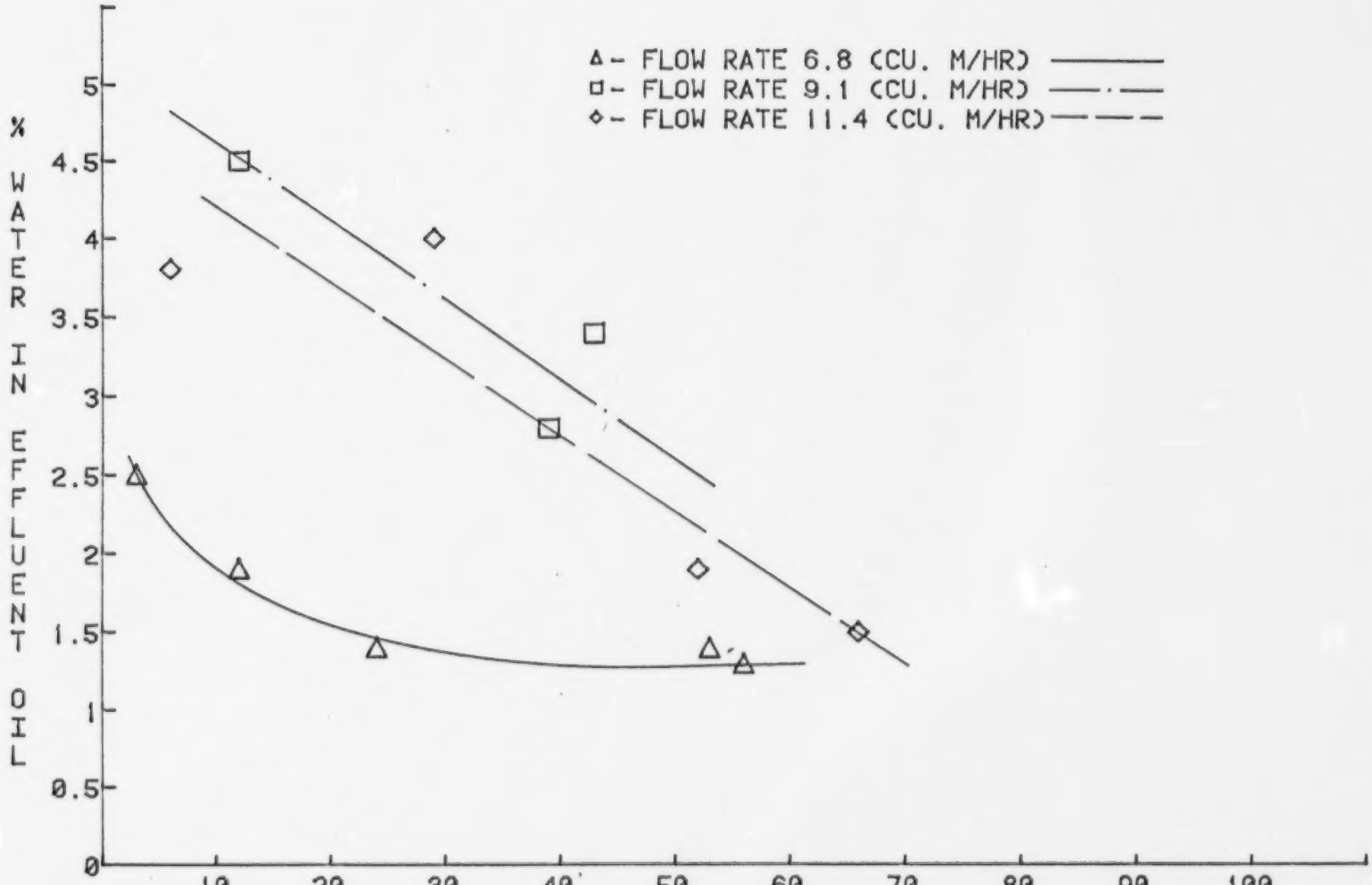

Figure 7 : SEPARATOR PERFORMANCE, MEDIUM OIL

This graph shows the effect on the oil effluent of varying the medium oil concentration in the influent introducted into the separator at three different flow rates. The effluent oil quality is expressed by the percentage of water in it.

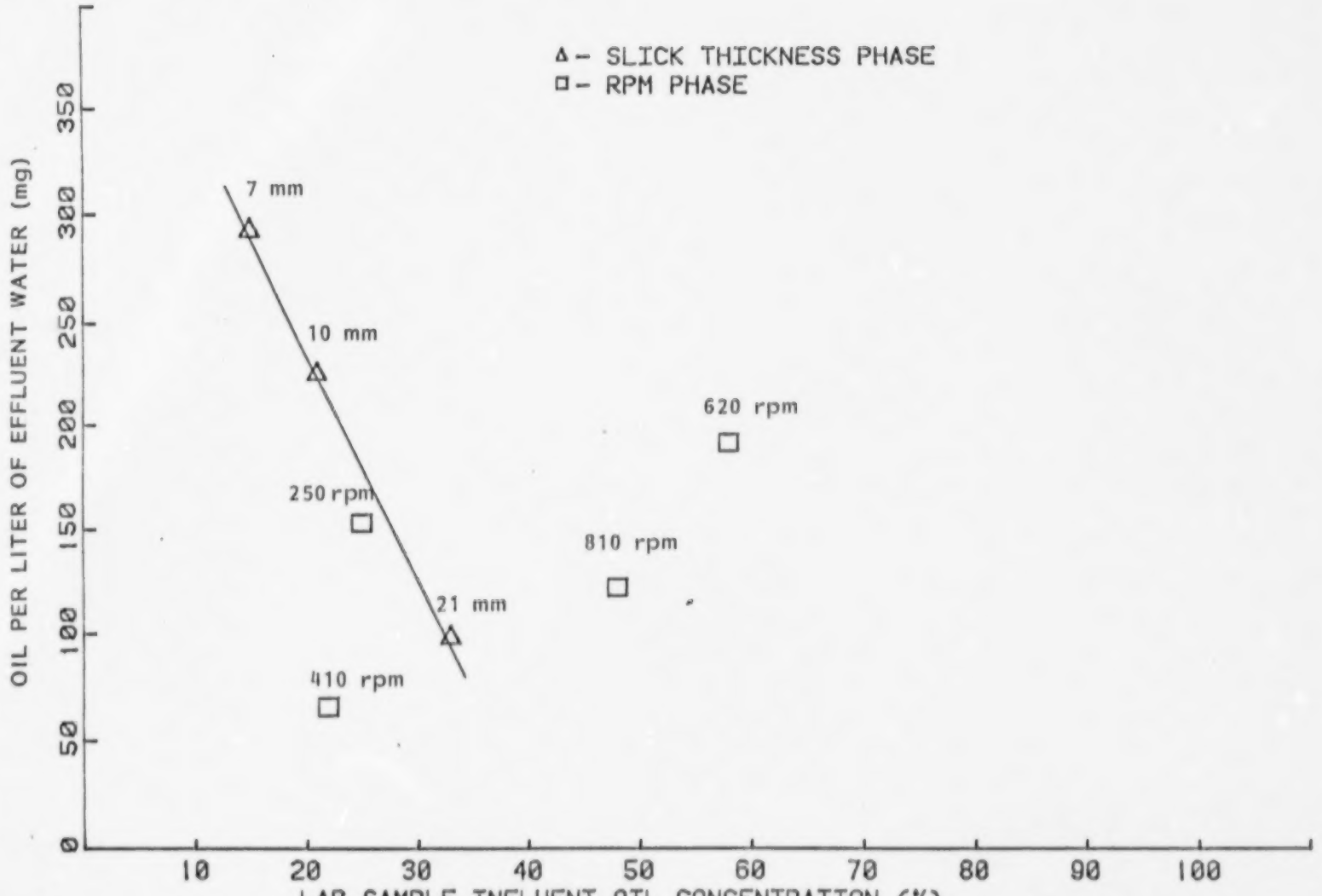

Figure 8 : SEPARATOR WITH SKIMMER PERFORMANCE, LIGHT OIL

This graph shows performance of the skimmer and separator as a system by showing the effect of varying the influent oil concentration on the concentration of oil per liter of effluent water. Two series of tests separately varied the light oil slick thickness and the skimmer propeller rpm.

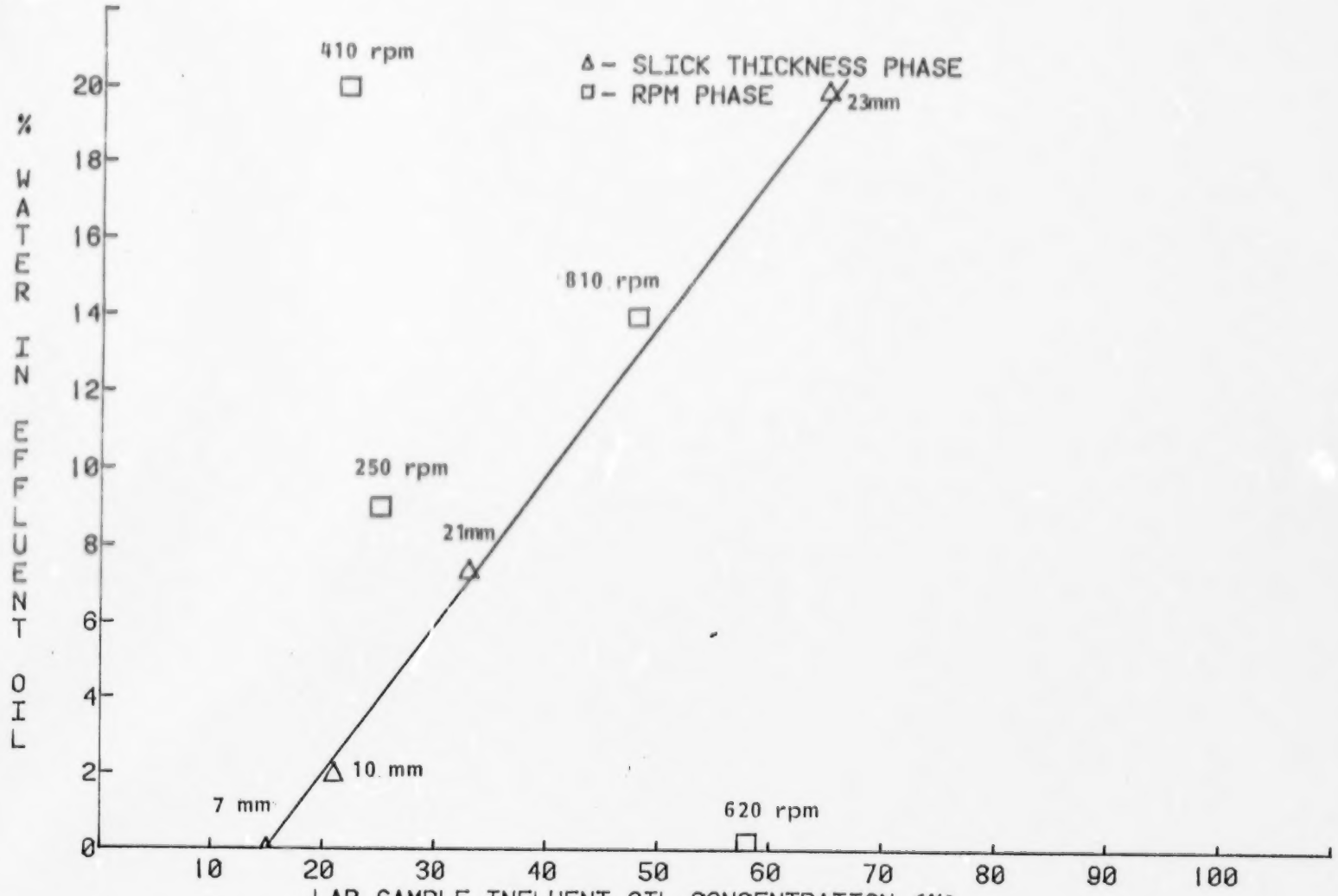

Figure 9 : SEPARATOR WITH SKIMMER PERFORMANCE, LIGHT OIL

This graph shows performance of the skimmer and separator as a system by showing the effect of varying the influent oil concentration on the percentage of water in effluent oil. Two series of tests separately varied the light oil slick thickness and the skimmer propeller rpm.

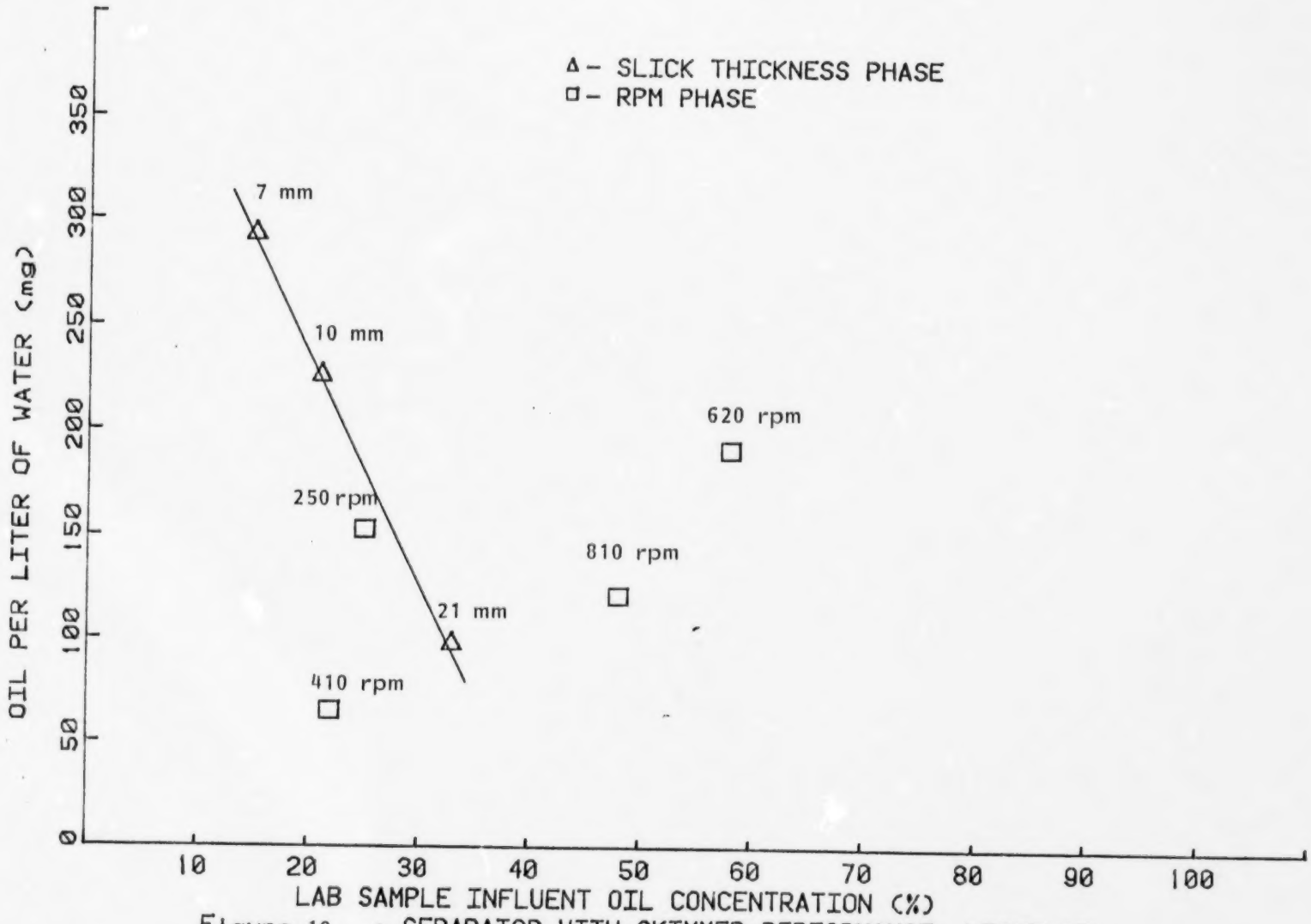

Figure 10 : SEPARATOR WITH SKIMMER PERFORMANCE, LIGHT OIL

This graph shows the performance of the skimmer and separator as a system. The effect of varying the influent oil concentration is shown by the amount of oil per liter of water. One series of tests also varied the slick thickness, another series varied the propeller rpm.